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Sustainable Materials Replacement for Prevention of Corrosion at Fort Lewis, WA

Final Report on Project FAR-21 for FY06

Richard G. Lampo, Thomas R. Napier,
and Richard L. Schneider

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Richard G. Lampo, Thomas R. Napier, and Richard L. Schneider

*Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
2902 Newmark Drive
Champaign, IL 61822*

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Abstract: This report documents a building reclamation project at Fort Lewis, WA, in which significant portions of the work were completed using market-available sustainable replacement materials. The replacement materials were selected on the basis of their being more resistant to corrosion and materials degradation processes than conventional construction materials, and also because they also are expected to provide long-term benefits to the U.S. Army in terms of operation and maintenance cost reductions.

The demonstration was applied to the reclamation and renovation of a World War II-era temporary wood frame chapel building, which was otherwise slated for demolition and off post landfill disposal. The structure was moved intact from its original site to the Sequalitchew EcoPark at Fort Lewis, to be renovated and reused as the installation's new Environmental Education and Conference Center (E2C2). This report describes project objectives, materials selection, and renovation activities to date. Existing performance data was compiled and reviewed, and selected physical testing will be conducted once all installation activities are complete. A return-on-investment analysis will be performed to verify the life-cycle cost benefits projected for the project in terms of operations and maintenance cost benefits, including the control and prevention of corrosion and building materials degradation.

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Preface

This demonstration is being performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Control and Prevention Project FAR21, “Sustainable Materials Replacement for Prevention of Corrosion at Fort Lewis, WA”; Military Interdepartmental Purchase Requests MIPR6FCERB1020, 20 Mar 06; MIPR6H6AG3CPC1, 15 May 06; and MIPR6HMBHDE097, 31 May 06. The proponent is the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), and the stakeholder is the U.S. Army Installation Management Command (IMCOM). The technical monitors are Daniel J. Dunmire (OUSD(AT&L)Corrosion), Paul M. Volkman (IMPW-E), and David N. Purcell (DAIM-FDF).

The work was jointly performed by the Engineering and Materials Branch (CEERD-CF-M), Facilities Division (CF), U. S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL, and the U. S. Army Engineer District Seattle (NWS). The ERDC-CERL OSD-CPC Program Manager is Dr. Ashok Kumar and the Project Officer is Mr. Vincent F. Hock (CEERD-CF-M). The Project Managers for this demonstration are Richard G. Lampo and Thomas R. Napier. The NWS Project Manager is Elizabeth A. Chien.

The primary customer is the Directorate of Public Works (DPW) , Fort Lewis, WA. Project stakeholders include:

- Mr. [Steve Perrenot](#), Director of Public Works, Fort Lewis, WA
- Mr. Paul Steuke, Chief, Engineering Division, DPW, Fort Lewis, WA
- Mr. Ken Smith, Program Manager, Environmental Operations Branch, DPW, Fort Lewis, WA
- Mr. Ron Norton, Solid Waste & Recycling Program Manager, DPW, Fort Lewis, WA
- Mr. Tom Shields (IMA-NWRO)
- Mr. Paul Volkman (HQ-IMA)
- Mr. David Purcell (HQ-ACSIM)
- Mr. Tom Tehada (NFESC)
- Ms. Nancy Coleal (AFCESA/CESM)

Also gratefully acknowledged for their support and assistance in this project are:

- Seattle District personnel:
 - Lisa Cass, Landscape Architect
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 - Anne Marie Moellenberndt, Mechanical Engineer
 - William B. Ninnis, Structural Engineer Technical Lead
 - Gregory L. Segal, Geotechnical
 - Tom Tolman, Architect
 - Jennifer L. West, Civil Engineer
 - Daniel Roper, Project Manager
 - Elizabeth Chien, Project Manager
- Metal Sales Manufacturing, Inc.
 - Mr. Jeff Crawford, Sales Representative
 - Mr. David Stermer, Materials Engineer
- James Hardie Company
 - Mr. Tim Larson, Sales Representative
 - Mr. Jason Ward, Product Development Engineer
- Premier Building Systems, Inc.
 - Mr. Todd Bell, Sales Representative
 - Mr. Joe Pasma, Materials Engineer

At the time this report was prepared, the Chief of the ERDC-CERL Materials and Structures Branch was Vicki L. Van Blaricum (CEERD-CF-M), the Chief of the Facilities Division was L. Michael Golish, (CEERD-CF), and the Technical Director for Installations was Martin J. Savoie (CEERD-CV-ZT). The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

The Commander and Executive Director of the U.S. Army Engineer Research and Development Center was COL Richard B. Jenkins and the Director was Dr. James R. Houston.

Executive Summary

This report documents the interim results of a demonstration of corrosion prevention and control technologies compatible with sustainable construction practices recommended by the Leadership in Environmental and Energy Design (LEED) evaluation system. Corrosion-mitigation technologies include high-performance materials designed to resist corrosion of both metals and nonmetals, as defined by NACE International. The general objective of the technologies is to reduce facility life-cycle costs through building service-life extension and reduction of maintenance requirements. The subject facility for this demonstration was a structurally sound World War II-era wood frame chapel building located at Fort Lewis, WA.

Durable, high-performance roofing and siding materials were selected for the exterior building envelope, and a structural insulated panel system (SIPS) was selected to reduce heat loss through the roof while meeting regional seismic resistance requirements. Concrete with a high fly ash content was specified for the foundation, and plastic lumber extruded from post-consumer waste materials was incorporated for corrosion resistance and long-term durability. Other sustainable design features were incorporated for purposes of achieving a minimum Silver LEED rating.

Installation of the sustainable corrosion-resistant technologies was accomplished using standard building trades tools, equipment, and practices. Completion of the renovation project was delayed by contracting issues between the contractor and the contract administrator, Seattle District. Upon completion of the construction, a formal life-cycle cost analysis will be executed to assess the cost impacts of the selected technologies. Energy consumption of the renovated building will first be simulated, then monitored in use during the heating and cooling seasons.

Because actual performance results will not be available for several years, manufacturer's published test and performance data have been compiled and reviewed to estimate the durability and economic benefits of the applied technologies. Exterior exposure and laboratory accelerated aging tests will be performed on the roofing and siding materials upon completion of the renovation. Observations to date indicate that the subject technologies are performing in the field as intended.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	$(F-32)/1.8$	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
mils	0.0254	millimeters
square feet	0.09290304	square meters

1 Introduction

1.1 Problem statement

The U.S. Department of Defense (DoD) spends billions of dollars every year on the operation, maintenance, repair, and rehabilitation of military facilities. Corrosion and corrosive nonmetal materials degradation account for a large percentage of that funding requirement. Because there are limited resources available, the DoD backlog of maintenance and repair requirements continues to grow, which has negative impacts on readiness, facility suitability for mission, and quality of life for building occupants.

DoD established the Corrosion Prevention and Control (CPC) Program to accelerate technology adoption in the area of high-performance durable materials, components, equipment, and systems in its infrastructure. The NACE International definition of corrosion encompasses the deterioration of both metals and nonmetallic materials resulting from a reaction to the environment.* A demonstration of corrosion-resistant high-performance building materials was proposed under the CPC Program as incorporated into an existing sustainable facility design project planned at Fort Lewis, WA. Fort Lewis has a robust established facility sustainability program whose objective is to comply with the applicable controlling Federal mandates, including:

- Executive Order (EO) 13101, *Greening the Government through Waste Prevention, Recycling, and Federal Acquisition*, which is directed toward waste reduction and conservation of resources.
- Executive Order (EO) 13432, *Strengthening Federal Environmental, Energy, and Transportation Management*, which directs Federal agencies to “construct or renovate buildings in accordance with sustainability strategies, including resource conservation, reduction, and use; siting; and indoor environmental quality.”
- Army-level directives for sustainable design and development on Army installations.

* National Association of Corrosion Engineers. 1984. *Corrosion basics: An introduction*. ISBN 0-915567-02-4. Houston, TX: National Association of Corrosion Engineers.

The integration of the Fort Lewis CPC and sustainable facility demonstrations was considered to be a good fit because both programs have the common objective of reducing facility life-cycle cost. The sustainability aspect of the subject demonstration addressed many topics beyond the scope of the CPC, such as reuse of existing buildings, reduction of energy consumption, and selection of materials that were produced with low environmental impact. However, both programs have overlapping goals in the area of materials performance and durability.

1.2 Objectives

The objective of this demonstration was to show how facility life-cycle costs may be reduced, and building service life extended, through the application of low- and no-maintenance construction materials that prevent corrosive materials degradation while reducing adverse environmental impacts and facilitating infrastructure sustainability. This report presents interim findings pertaining to the demonstration.

1.3 Approach

The subject demonstration involved three main areas of activity:

- reclamation of an unused World War II-era wooden building to avoid demolition, waste-handling, and landfilling costs
- applying sustainable, high-performance construction materials selected for their ability to resist corrosive degradation processes
- applying sustainability principles in developing an adaptive reuse design for the building, including a minimum target LEED–NC (New Construction) rating of Silver.

The selected building was the North Fort Chapel, a temporary structure designed to have a service life of 3 years. World War II temporary wood buildings like the chapel have demonstrated remarkable service longevity, and many have been used productively without interruption for almost 70 years. Various Army demonstrations have been performed showing how such buildings may economically be adapted for modern reuse, and also how high-quality construction materials may be recovered and reused from buildings scheduled for demolition. The North Fort Chapel was selected to serve as the installation's Environmental Education and Conference Center (E2C2), a space for meetings and community outreach located

at the new Fort Lewis EcoPark, a project with multiple military training, environmental, and sustainability technology goals.*

The roofing and siding on the chapel had deteriorated and required replacement. Structurally, the building was in good condition, and required only reinforcement with shear panels to comply with current seismic design criteria. In order to recover the chapel building for its intended sustainable reuse, the structure was jacked off its original foundation on North Fort Lewis and moved over 1 mile to its new site at the EcoPark, a recovered portion of the decommissioned Fort Lewis landfill.

Because building envelope performance, primarily roofing and siding, is the main determining factor in actual building life-cycle cost, materials were selected not only for their sustainable characteristics but also for high performance in terms of resisting environmental corrosive processes. The roofing and siding materials were specified to have high resistance to degradation caused by the corrosive impacts of oxidation and ultraviolet light. Sandwich-type insulating panels were specified for both their energy conservation properties and their structural stiffness for seismic resistance.† Other durable, sustainable materials incorporated into the project were concrete with a high fly ash content and recycled plastic lumber components. Other sustainable features not directly related to the CPC Program were high-efficiency heating and lighting equipment, optical daylighting technologies, and interior materials with low emissions of volatile chemicals.

Verification of technology performance will be conducted in two phases. The first phase will be a review of published performance data for the selected materials and technologies. The second phase will consist of exposing materials samples at the E2C2 building site for periods of 6, 12, and 24 months as well as longer-term specimens. Performance will be determined by visual inspection and handling. Also, selected accelerated aging laboratory tests will be performed on the roofing and siding materials. Electro-impedance spectroscopy (EIS) field measurements will also be taken from the metal roofing samples.

* For background information, see <http://fortlewisecopark.org/>.

† Originally the sandwich panels were to be used for insulation and structural stiffness in the walls, but project managers were able to cut first costs by instead using recovered plywood panels from an onsite deconstruction project. The panels were used instead as deck material beneath steel cladding.

Life-cycle cost and energy consumption analyses will be performed to help estimate the future return on investment for implementing the technologies. The energy studies will include both computer simulations and, throughout an entire heating and cooling season, in-place monitoring.

2 Technical Investigation

2.1 Project overview

In 2002, Fort Lewis closed the last operating cell of its landfill property. The Fort Lewis Environmental Division is converting that land into the Fort Lewis EcoPark, a multipurpose site that was planned to include an Environmental Education and Conference Facility (E2C2). The mission of the EcoPark includes restoration of native prairie, woodland, and wetland habitats. The purpose of the E2C2 is to provide training and conference space for installation personnel, a venue for public meetings and outreach, and to showcase the application and cost-effectiveness of sustainable construction materials and energy-efficient technologies. The conversion of the chapel to a modern use addressed both Fort Lewis' sustainability interests and provided a platform for ERDC-CERL's CPC technology demonstration.

Figure 1 shows the North Fort Chapel in its pre-project condition and location. Figure 2 shows a computer-assisted illustration of the exterior materials and fenestration as designed for the E2C2 demonstration.



Figure 1. The existing chapel building before relocation.



Figure 2. Computer-assisted rendering of completed E2C2.

Fort Lewis has relocated the Chapel building to the Eco-Park, where it is being renovated into a sustainable structure. Figure 3 shows the building being transported; Figure 4 and Figure 5 show it in place prepared for renovation.



Figure 3. Relocating the Chapel building.



Figure 4. The relocated building's exterior.



Figure 5. The relocated building's interior.

2.2 Materials selection

Failure in a building's roofing system and exterior envelope materials creates a costly maintenance and repair (M&R) burden in the Army. The failure of these systems also damages interior finishes and furnishings, and over time can degrade the building's structural integrity and mission-effectiveness. In the worst cases, the only options may be heroic repair efforts or building demolition and replacement.

The Army's Annual Summary of Operations (commonly called the *Red Book*) summarized Real Property Maintenance Activities (RPMA) and expenditures. The final edition was published in 1997, but it illustrates the general magnitude of expenditures for various real property categories. Roughly 25% of the total Army RPMA expenditure was invested in building M&R. Commercial data sources, such as the *Whitestone Building Maintenance and Repair Cost Reference*, suggest maintaining exterior systems and interior finishes can consume 25 – 40% of a building's M&R expenditures. For purposes of addressing corrosive degradation of materials, the CPC portion of this demonstration put emphasis on exterior components that are significantly affected by interaction with the environment.

2.2.1 High-performance roofing system

The selected high-performance roofing system is a standing-seam metal design. Because there is a substrate onto which the material is fastened and the roof cladding does not carry loads to framing members, this metal roofing system is appropriate for the application. The base material is Galvalume, a 24 gage, 50,000 pounds per square inch (psi) carbon steel sheet coated with an aluminum-zinc alloy. The Galvalume material is coated with Kynar 500, a polyvinylidene fluoride (PVDF) resin coating that is accepted throughout the architectural and construction professions as the premier coating for architectural metals. Furthermore, Kynar coatings are now commonly formulated to achieve a Solar Reflectance Index (SRI) of over 70%, even with darker colors. This characteristic is important to reduce interior heat gains, and therefore lower cooling demand and cost. Kynar coated Galvalume roofing typically carries a 25-year warranty against rusting, peeling, blistering, and other similar deterioration. Beyond periodic inspection, there should be no maintenance required for the life of this system.

The roofing panels are laid in the direction of the roof slope, continuous from the ridge to the eave. Panels are attached to the roof deck with concealed fasteners and attached to each other by crimping seams continuously over the fasteners. The seams are designed to remain above the runoff. Thermal expansion and contraction are accommodated through the concealed fasteners to avoid overstressing connections or seams. The roof is a relatively steep pitch (6-1/2:12), designed to shed water as opposed to prevent it from penetrating the roof. Pitched systems are less susceptible to leakage. The fastener types and spacing are designed to achieve an Underwriters Laboratory (UL) 90 rating for resistance to wind uplift, which means that it will resist an uplift force of 90 pounds per square foot (psf).

This type of standing-seam metal roofing system is available from a number of manufacturers. The only constraint on vendor selection was that the company had to provide a complete roofing system of the specified materials, including all flashings, curbs, rake trim, and fabrications, to ensure appropriate fit and water tightness. A general sheet metal fabricator with no specialty in roofing systems was not acceptable for this demonstration.

The installing contractor selected a roofing system manufactured by Metal Sales Manufacturing, Inc., Sellersburg, IN, which is a well known source of standing-seam metal roofs. The company uses sheet steel goods with 23% post-consumer and 7.3% post-industrial recycled content. Figure 6 shows an example of the standing seam metal roofing used for the E2C2 project, as implemented on a separate project by the installing contractor.



Figure 6. Example of standing-seam metal roof system.

2.2.2 High-performance siding system

A selected durable siding material consists of a glass-fiber reinforced polymer-cement laminate incorporating a moisture drainable system that reduces the potential for material degradation due to water entrapped in the wall cavity. This material is manufactured in several dimensions and styles to accommodate the various types of applications required on a building. Horizontal siding panels 5/16 in. thick and are applied to the majority of the wall area. They are nailed to the wall in conventional ship-lap fashion, from bottom to top, whereby the nails for one board are covered by the board above. The boards are available in 14 ft lengths, and it is desirable to avoid butt joints to the greatest extent possible. Where butt joints are unavoidable, the joint is back-flashed with a piece of bituminous building paper. Caulking joints is not recommended. While the siding material itself is inert and not susceptible to thermal expansion and contraction (unlike metal or vinyl siding), it is nevertheless advisable to leave some space between boards to account for general building movement. Areas above and below window openings are covered with a 7/16 in. thick sheet version of the same material, which is nailed into the wall framing in those places. Vertical battens 3/4 in. thick trim the ends of the ship-lap siding at window openings and corners. Nails are corrosion-resistant, typically galvanized, and exposed nail holes are sealed with color-matching acrylic caulk. Panels and battens are screwed into the framing so they can be removed and reinstalled when the windows are installed at a later date. Ordinarily, windows would be installed prior to the siding, and all siding materials would be nailed in place, but construction scheduling issues required a modified approach.

In order to eliminate the need for painting cycles, the siding materials were procured pre-finished in the desired colors.

ERDC-CERL and Fort Lewis selected the James Hardie Company, Fontana CA, whose products have the reputation of being the premier materials of their type. The products — Hardieplank, Hardiepanel, and Hardietrim — are all available with a 25-year warranty on their ColorPlus coating, which is a factory-applied water-based acrylic coating. Figure 7 shows an example of Hardieplank ship-lapped siding in place on a separate project managed by the installation contractor.



Figure 7. Example of Hardiepanel ship-lapped siding.

Structural upgrades were required to conform to current seismic resistance criteria. It was originally anticipated that a sandwich-type SIPS would be applied to the exterior walls to provide a structural diaphragm and insulation within one product. It was later determined that plywood sheathing, salvaged from a deconstruction project at Fort Lewis, could be applied to the walls for the seismic upgrade, but SIPS would be appropriate for the roof to create a diaphragm (Figure 8). Both faces of the roofing sandwich panels were specified as 7/16 in. thick oriented strand board (OSB), and the core was specified as expanded polystyrene (EPS), comprising a total thickness of about 10 in. EPS is not the most efficient insulating material available, with polyurethane and polyisocyanurate providing a higher R-value per inch of thickness. However, the EPS contributes less to global warming because the blowing agents used in its manufacture offgas less than the other materials. While not widely recycled at present, polystyrene is recyclable. These properties were judged to make polystyrene the preferable material from a sustainability standpoint. Premier Building Systems, Tacoma WA, was selected as the SIPS installing contractor.



Figure 8. Sandwich-type SIPs panel being attached to roof.

Other high-durability, sustainable materials incorporated into the E2C2 included high fly-ash content concrete in the foundation, and recycled plastic lumber for exterior stairs and *briese soliel* (sunshades).

The concrete mixture included 15.32% fly ash content. Fly ash is a byproduct of coal combustion and historically has presented a waste-disposal problem. However, fly ash has pozzolanic properties. When incorporated into concrete it reduces amount of cement necessary to achieve a given compressive strength. Because cement production is very energy-intensive, substituting some of the cement with an industrial byproduct is a sustainable practice. Fly ash has also been found to improve the resistance to moisture penetration, which reduces freeze-thaw damage that can initiate corrosion and deterioration of reinforcing steel. Finally, fly ash improves the workability of concrete, which reduces the occurrence of voids within the interior of the member.

Recycled plastic lumber is used on exterior stairs and the sunshades. It consists primarily of high-density polyethylene (HDPE), 93% recycled, with polyester added for reinforcing to reduce creep. Recycled plastic lumber is typically extruded to the same dimensions as standard construction lumber. Recycled plastic lumber structures require virtually no mainte-

nance, and have been in place for 15 years and longer with no evidence of corrosive materials deterioration.

2.3 Sustainability features

Other features of the renovation design contribute to the overall sustainability of the building and LEED rating. Although not directly related to CPC Program objectives, these features were central to the original project concept and are briefly listed below:

- The E2C2 is being developed on an underutilized site, which will make the former landfill available for troop training and recreational activities while avoiding the conversion of natural habitat to military infrastructure.
- The building frame shell, most sheathing, and additional necessary framing lumber come from reused or recovered sources.
- Optical solar tubes are cut into the roof for passive daylighting of the building's interior.
- The *briese soliel* (sunshades) are installed on the building's southern exposure to admit sunlight and radiant heat during winter months while shading the windows and reducing solar gains during summer months.
- Operable windows provide passive ventilation during transitional seasons.
- Recycled-content glass fiber and recycled cotton insulation are candidate wall cavity insulation materials.
- Most of the existing wood flooring will be reused in place.
- Interior finishes, including paints and the floor finish, were selected for low emission of volatile compounds.
- Water-conservative fixtures will be installed, including waterless urinals and dual-flush toilets. (Composting toilets were not selected because they would represent a new, ongoing maintenance activity for the Fort Lewis DPW.)
- Energy-conserving features include a high-efficiency ground-source heat pump and tankless water heaters.

2.4 Installation

Because the subject technologies involved several major building components and a significant portion of the structure, installation was executed using a mostly conventional construction sequence.

MCS Environmental Systems, Inc., installed the subject technologies under a contract with the Corps of Engineers Seattle District. MCS was performing other work at Fort Lewis, and had an established reputation for quality and cooperation with both Fort Lewis and Seattle District. ERDC-CERL developed the project Scope of Work (SOW), which was transmitted to Seattle District with a Military Interdepartmental Purchase Request. Seattle District incorporated the SOW into its contract with MCS. The direct contractual relationship was between MCS and Seattle District. Installation activities essentially followed conventional building trades practices. Features of note are described below.

2.4.1 Building relocation

While CPC objectives were not directly impacted by moving the building, the ability to relocate a structure can be a major contributor to the overall feasibility of extending the lives of WWII-era buildings. The building move was executed by Northwest Structural Moving in an impressive and trouble-free fashion (Figure 9). The success of this portion of the undertaking illustrates the importance of retaining knowledgeable, capable, and experienced service contractors.



Figure 9. North Fort Chapel in transit to new location.

2.4.2 Foundation construction

The foundation was installed in place beneath the relocated building. It is possible to construct a foundation first, then set the relocated building on

it, but the critical interface and dimensional tolerances are more readily accommodated by building the foundation in place. The chapel was set on cribbing (temporary supports), and then lowered after the foundation was constructed below it. Figure 10 and Figure 11 show the building supported by cribbing, and the footing forms and reinforcing in place prior to placing the footing concrete, respectively. Figure 12 shows the completed foundation from the crawl space.



Figure 10. Underside of the building in place, supported by cribbing.



Figure 11. Footing forms and reinforcement bars under the building.



Figure 12. Finished foundation.

2.4.3 Sheathing and insulation

Once in place, the building was sheathed with $\frac{1}{2}$ in. plywood salvaged from a deconstruction project MCS was conducting on Fort Lewis. The chapel's original diagonal 1 x 8 in. sheathing was left in place; the added the plywood sheathing creates a structural diaphragm to provide seismic resistance, as required by building code (Figure 13). In preparation for the siding installation, 1 in. thick polyisocyanurate insulation and air barrier were installed over the plywood sheathing (Figure 14).



Figure 13. Salvaged plywood sheathing.



Figure 14. External insulation and air barrier in place.

2.4.4 Insulated roof panels

Installation of the SIPS followed common carpentry practices. Most panels are 8 ft wide and 24 ft long; narrower panels are used at the front and rear of the roof. Panels were lifted into position with a light crane. The panels are laid edge-to-edge and run the full dimension from the ridge to the eave. As the panels are 10 in. thick, 13 in. screws were used to penetrate the depth of the panel and anchor into the purlins that frame the roof. These fasteners were placed every 12 in. on center. The fastening schedule was developed by the MCS structural engineer to resist wind uplift loads, and approved by Seattle District. Figure 15 shows the placement of the SIPS.



Figure 15. SIPS panel being placed.

2.4.5 Siding installation

The Hardieplank siding was installed similar to a conventional solid siding material. The company's representative cautioned that the manufacturer's installation instructions be diligently followed. Nailing schedules, which describe fastener types and spacing, have been developed to satisfy regional wind loading criteria; adherence to these schedules is important to prevent wind damage. Pneumatic nailing is appropriate, although installers must also be careful to not over-nail or under-nail, especially with the color-treated products. Hardieplank was used for the horizontal ship-lap siding, and Hardiepanel was used to cover window openings and to accent the windows once they are in place.

As the siding products have a cement content, cutting siding must be performed to minimize dust and avoid inhalation of silica fibers. Score-and-snap is the preferred cutting method. These products can be cut with a circular saw using abrasive blades, although a dust collection system (preferably with a HEPA filter) is recommended. The manufacturer also recommends that sawing be performed only outdoors.

Figure 16 and Figure 17 shows installation of the panel siding and a detail of the ship lap siding, respectively.



Figure 16. Installation of Hardieplank siding.



Figure 17. Hardieplank siding detail.

2.4.6 Corrosion-resistant metal roof

The standing-seam metal roof was installed according to conventional practice. Resistance to damage due to wind uplift is a critical. MSM developed guidance for fastener types and spacing that must be diligently observed. That guidance calls for the concealed fasteners to be spaced at 4 ft, 0 in. when fastened to 5/8 in. OSB substrate. However, because the SIPS facing was 7/16 in. OSB, the fastener spacing was reduced to 2 ft, 0 in. in order to meet the Underwriters Laboratories wind uplift rating of UL 90*. Figure 18 shows the roofing in place.



Figure 18. Standing seam metal roofing in place.

2.4.7 Construction delays

Construction delays occurred starting in June 2007 due to a contracting dispute between Seattle District and MCS. However, in terms of the CPC project objectives, all technologies of interest were successfully installed except for the recycled plastic lumber components. The construction delays mainly have affected completion of the building's interior finishes, mechanical, and electrical systems that comprise a significant portion of the project's sustainability features.

* UL 580. 2006. *Tests for Uplift Resistance of Roof Assemblies*. Northbrook, IL: Underwriters Laboratories.

It is expected that plastic lumber installation and other tasks remaining under this funding will be completed during summer 2008.

2.5 Technology monitoring

As of this writing, the building systems in place are performing as intended. After the SIPS, siding, and roofing systems were installed, periodic visual inspection performed by Fort Lewis, Seattle District, and ERDC-CERL personnel indicate that no water or moisture penetration is occurring. Inspections have also been performed after the severe weather events occurring in the Fort Lewis region during the winter of 2006 – 2007, with no damage, deterioration, or leakage visible.

2.6 Data collection

Within the building industry, verification of material and system performance is confirmed primarily through existing data. This data consist of compliance reports issued by model building code organizations, certifications from manufacturers that their products conform to applicable specifications and standards, and laboratory test documentation developed either by manufacturers or third-party testing laboratories. With some exceptions, such as concrete compressive strength tests, job-specific testing generally is not performed. Construction contracts require contractors to submit previous technology performance or test documentation, which is generally published as products are introduced to the market. If the documentation is complete and credible, the material is accepted.

No testing was conducted prior to, or as the subject technologies were installed. Available performance data were submitted to and reviewed by Seattle District as part of the quality control/quality assurance process.

ERDC-CERL compiled existing performance and test data for the SIPS, the standing-seam metal roofing, and the Hardieplank siding products. Sources include manufacturers' published data, unpublished data provided by the manufacturers, and Legacy Reports developed by the International Code Compliance Evaluation Service (ICC-ES). Upon complete installation of all technologies being demonstrated under the CPC, ERDC-CERL will conduct specimen tests as follows.

Electrochemical impedance spectroscopy (EIS) will be used as a non-destructive method of evaluating coating degradation and the onset of cor-

rosion on the steel substrate. Readings will be taken periodically (the period to be determined) to identify the rate of any corrosion that may occur, if any. Taking readings on an area of the roof accessible by extension ladder is possible. Taking readings from samples on the exposure rack (see below) may also be a viable method.

Exposure racks will be built to simulate south exposure (the most severe) of roofing and siding materials. Samples will be exposed for six months, one year, and two years. A set of samples will be kept unexposed as the point of reference. Upon retrieval of the samples, they will be visually examined for failure in the coating or surface, which will include cracking, crazing, blistering, delaminating, staining, or color fade.

ERDC-CERL will also perform accelerated weathering tests on roofing and siding samples according to the applicable ASTM test methods.

Historic energy consumption for the chapel is documented and will be used as a basis for comparison to evaluate the performance of the E2C2 in its final configuration. Energy use will be analyzed using a Building Information Model (BIM) to simulate energy consumption. Energy modeling was successfully applied to new building designs at Fort Bragg by ERDC-CERL, and was chosen for this demonstration because of its simplicity, as opposed to more sophisticated commercial analysis such as Trace-Train or Energy-Plus.

A simple BIM will be created using Autodesk Revit, ArchiCAD, or Bentley TriForma. Once a three-dimensional model has been developed, the gbXML export feature will be used to export the building configuration and geometry into Green Building Studio*. Multiple energy analysis runs can then be submitted and the results will be compared to determine the most energy saving options which can be integrated into the project. Green Building Studio menu options allow the user to test different windows, wall and roof construction/insulation values, orientation, and a variety of lighting, control, and mechanical systems. Energy analysis reports will be generated and compared to identify cost effective energy saving options that can be integrated into the building renovation.

* A web-based energy and carbon analysis tool of Autodesk, Inc., San Rafael, CA.

3 Discussion

3.1 Metrics

3.1.1 SIPS

The performance characteristics relevant to the SIPS include primarily strength and dimensional stability properties. As they are applied to this building to develop a structural diaphragm, the shear and diaphragm characteristics are relevant. To prevent wind damage and the fastener withdrawal properties are important. These properties have been verified through MCS's structural design and Seattle District's review of the design and details. The properties are evaluated against the prevailing building code, which at Fort Lewis is the International Building Code. Conformance to the Uniform Building Code is allowed on a "legacy" basis.

- Concentrated load (IBC or UBC)
- Diaphragm load (IBC or UBC)

As the SIPS sandwich panels not directly exposed to weather, resistance to the forces of weather and ultraviolet exposure is of less concern. However, in the event that a building's skin does fail, behavior when exposed to water or moisture is relevant. The properties of the core material being evaluated, and the methods by which they are evaluated are as follows.

- Compressive strength (ASTM C 578)
- Dimensional stability (ASTM C 578)
- Flexural strength (ASTM C 578)
- Water absorption (ASTM C 578)
- Vapor permeance (ASTM C 578)

The performance characteristics relevant to roofing and siding materials include primarily the resistance to moisture, ultraviolet exposure, chemicals, and other environmental and physical attacks.

The properties being evaluated, and the methods by which they are evaluated are as follows.

3.1.2 Standing seam metal roofing

- Color change and conformity (ASTM D 2244)
- Accelerated weathering (ASTM D 4587 or G23)
- Humidity (ASTM D 2247 & D 714)
- Salt spray (ASTM B 117)
- Chemical pollution (ASTM D 1308)
- Gloss (ASTM D 523)
- Pencil hardness (ASTM D 3363)
- Reverse impact (ASTM D 2794)
- Flexibility (ASTM D522)
- Abrasion (ASTM D 968)
- Flame spread (ASTM E 84)

3.1.3 Hardieplank siding

- Impact resistance (ASTM E 695)
- Abrasion resistance (ASTM E 968)
- Accelerated weathering (ASTM G 153)
- Mildew resistance (ASTM D 3273)
- Salt spray resistance (ASTM B 117)
- Absorbtion; freeze/thaw (ASTM C 67)

3.2 Results

The results available at this writing are limited to visual observation. The fly ash concrete foundation system, SIPS, the Kynar-coated Galvalume standing seam metal roof system, and the Hardie siding products were all successfully installed with conventional building trade practices. All systems appear to be performing as intended, as there has been no failure in the building envelope observed, even after severe weather events.

The following sections summarize published and unpublished performance data about each technology as compiled by ERDC-CERL.

3.2.1 SIPS

The structural analysis developed by MCS Environmental prior to installation was performed by a Registered Professional Engineer licensed in Washington, and reviewed by Seattle District. The structural sufficiency of this application was verified through this process. Other performance data are as follows.

- Maximum allowable diaphragm load: 425 plf when screws are spaced at 12 in. (ICC-ES Legacy Report NER-633)
- Maximum allowable concentrated load = 2,040 to 4,680 lb, depending on detailing, (ICC-ES Legacy Report NER-633).

The following apply to the EPS core, as established by ASTM C 578. Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation

- Compressive strength: Minimum 13 psi
- Dimensional Stability: Maximum 2.0% change in any dimension
- Flexural strength: Minimum 30 psi
- Flexural strength: Minimum 30 psi
- Vapor permeance: Maximum 3.50 perms with 1 in. sample
- Water absorption: Maximum 3.0% volume change after total immersion
- Net thermal transmission rate: $R = 3.85/\text{in.}$ steady-state average rate.

3.2.2 Standing seam metal roofing

The structural analysis developed by MCS Environmental prior to installation was performed by a Registered Professional Engineer licensed in Washington, and reviewed by Seattle District. Resistance of this application to wind uplift at 90 mph (UL 580) was verified through this process. Other performance data are as follows. Test data, below, were provided as certified laboratory test reports by the Valspar laboratories. All reports were certified by a notary public.

- Color change: Less than 2 ΔE Hunter Units (ASTM D 2244) .
- Accelerated weathering: 5,000 hours with no cracking, peeling, blistering, loss of adhesion of the protective coating, or corrosion of the base metal (ASTM 4587) .
- Chalking: 8 or better (ASTM D 4214, Method A).
- Humidity: 3,000 hours at 100% humidity at 100 degrees F; test rating 10 -- no blistering, cracking, creepage, or corrosion (ASTM D 2247)
- Salt spray: 1,000 hours; test rating 10 (field) – no blistering or cracking; test rating 7 (scribe) 1/16" creepage (ASTM B 117) .
- Chemical pollution (ASTM D 1308, covered spot test procedure 7.2):
 - 10% hydrochloric acid solution – 24 hour test; no visible changes
 - 20% hydrochloric acid solution – 18 hour test; no bleaching
 - 20% sulfuric acid– 18 hour test; no bleaching
 - 25% sodium hydroxide – 1 hour test; no color change, no blistering

- 20% muriatic acid – 15 minute test; no color change, no blistering
- Gloss: 30 or less on a 60-degree geometry (ASTM D 523).
- Pencil hardness HB minimum using Eagle Turquoise pencils (ASTM D 3363).
- Reverse impact: 5/8" ball indenter (Gardner Impact Tester; no cracking, no loss of adhesion, either direct or reverse impact (ASTM D 2794).
- Flexibility: No evidence of cracking, no loss of adhesion to the point of metal rupture (ASTM D522).
- Abrasion: 67 liters total sand (ASTM D 968).
- Flame spread: Class A (0-25) (ASTM E 84).

3.2.3 Siding materials

Allowable loads and attachments (fasteners and spacing) are described by the ICC-ES Legacy Report NER-405. The structural analysis developed by MCS Environmental prior to installation was performed by a Registered Professional Engineer licensed in Washington, and reviewed by Seattle District. Resistance to wind damage (i.e., detachment from negative pressure) was verified through this process. Other performance data are as follows. Test data, below, were provided by the James Hardie Company. All reports were certified by a notary public.

- Water absorption: <36% by mass (ASTM C 1185).
- Water tightness: No drop formation, by observation (ASTM C 1185).
- Moisture content: 5% (ASTM C 1185).
- Moisture movement: <0.05% linear change under 30 – 90% relative humidity (ASTM C 1185).
- Flexural strength: >1050 psi wet, conditioned sample, >1450 psi equilibrium conditioned sample (ASTM C 1185).
- Thermal conductivity: 2.07 BTU/hr/sq ft ; R = 0.15 (ASTM C 117)
- Thermal resistance: R = 0.15 (ASTM C 117)
- Warm water resistance: No visible cracks or structural alteration, by observation (ASTM C 1185)
- Heat / rain resistance: No visible cracks or structural alteration, by observation (ASTM C 1185)
- Freeze / thaw resistance (ASTM C 1185):
 - No visible cracks or structural alteration, by observation
 - 3.0% mass loss; > 80% wet retention
- Heat / rain resistance: No visible cracks or structural alteration, by observation (ASTM C 1185)

- UV accelerated weathering: No visible cracks or structural alteration, by observation (ASTM G 23)
- Surface burning (ASTM E 84):
 - Flame spread index = 0
 - Smoke development index = <5
 - Fuel contribution = 0
 - NFPA Class A
 - Uniform Building Code Class 1
 - International Building Code Class A
- Combustibility: Noncombustible (ASTM E 136)
- Fire resistance rating: 1-hour, (ASTM E 136, as listed by ICC-ES NER-405)

3.3 Lessons learned

When undertaking a project using high-performance materials that have not yet been widely adopted in Army construction practice, it is essential for project managers and contractors to fully understand the installation methods recommended by the manufacturer to ensure proper system performance. Seemingly small details (e.g., pre-installation handling, fastener spacing and torque) may have a large impact on the product's actual level of performance or customer satisfaction in service.

Similarly, design and construction guidance published by industry standards organizations must be fully understood and observed in order to ensure compliance with building codes. Design and construction details must either conform exactly to published specifications for critical structural and life-safety codes (e.g., seismic resistance, wind uplift) or else be verified as equivalent to those specifications through engineering analysis.

If feasible, it is preferable to integrate building system design instead of procuring components separately. For example, the SIPS panels were fabricated to use 7/16 in. OSB skins, which is fully adequate in terms of unit strength. The Galvalume roofing material, however, included connector instructions that assumed the use of 5/8 in. OSB in order to meet UL 90 wind uplift requirements. A suitable modification of the connection details was developed and verified by project engineers to accommodate the thinner OSB, but that additional design step may have been avoided if both the SIPS and Galvalume envelope material had been procured as a complete roofing system that was specified to meet UL 90.

Workmanship quality control was a problem during installation of the fiber-reinforced cement siding. In this demonstration, the assigned work crew did not have previous experience with the material being applied. Although installation methods for the Hardie siding materials are essentially the same as for traditional materials, some manufacturer installation details affecting fit and finish were not observed, resulting in an unsightly job that was not acceptable to the Fort Lewis DPW. Although quality control is a concern on all construction projects, it is important for project managers to fully understand and communicate any installation details for high-performance materials that depart from default methods used with conventional materials. In this project, the correct installation details were not obscure or highly technical, so they could easily have been executed correctly the first time by a crew experienced with the materials.

As in many standard construction projects, a contract dispute caused a delay in the work schedule. However, in projects using high-performance materials that are not yet widely implemented in DoD construction practice, it is especially important that the contract documents leave no room for differing assumptions or interpretations by the contractor, the contract manager, the project manager, and the customer. For example, the requirement for an “experienced” installation crew should be explicit and thorough about the type of experience that is necessary.

Finally, diligent quality assurance and contract oversight are necessary throughout the project. It is understood that the largest contracts (e.g., tens of millions of dollars) must have the highest priority for monitoring and oversight resources. However, high priority for those resources also should be considered for smaller projects that use emerging facility technologies and promise large, long-term returns on investment in the form of low corrosion prevention and control requirements and highly efficient energy conservation.

4 Economic Summary

4.1 Costs and assumptions

4.1.1 Initial and life-cycle costs

The hypothesis for the project was that renovating the old North Fort Chapel for use as the E2C2 is economical and sustainable because it will add an extra 25 – 50 years of low-maintenance, energy-efficient service life to an otherwise obsolete structure. The benchmark for affordability is assumed to be that the chapel could be relocated, renovated, and operated for 50 years at a cost comparable to demolishing the building (including debris handling and disposal), designing and constructing a replacement building, and operating the new building for 50 years.

Based on Army guidance, construction of a similar building for use as an educational, community service, youth, or recreation facility would be programmed at approximately \$235 – 250/sq ft*. That figure includes the building only, with no site development, antiterrorism/force protection (ATFP), utilities, general construction contract requirements, location adjustment, local tax, or escalation factor. Furthermore, the figure does not include any extraordinary features for sustainability, high-efficiency energy systems, or documentation for certification under LEED. A reasonable rough estimate for total construction contract cost including those extra considerations would be at least \$300/sq ft. At approximately 3,500 sq ft, the new building would cost in excess of \$1.1 million.

It also should be noted that a new building would not produce a literal replacement of the chapel in terms of certain high-quality construction details incorporated into the original building. For example, built-up trusses similar to the Chapel's construction would cost at least 30% more per board foot of lumber than a conventional shop-fabricated truss layout. The tongue-and-groove roof deck similar to the Chapel's would cost five times the cost per sq ft as plywood sheathing that would be used with standard contemporary wood framing methods. Seattle District and Fort Lewis Public Works personnel estimated replacing the chapel with the same materials and methods would cost roughly \$1.5 million. Therefore, the benchmark

* Directorate of Civil Works – Engineering and Construction. 11 February 2008. *PAX Newsletter* 3.2.2. Washington, DC: Headquarters, U.S. Army Corps of Engineers.

frame of reference for E2C2 first cost is assumed to be roughly \$1.5 million.

Even before an energy consumption simulation is performed, it is self-evident that the new E2C2 will perform dramatically better than the chapel given that the building was originally constructed without thermal insulation and that the E2C2 building will include high-efficiency heating and energy-saving systems. A potentially higher first cost for energy-conservation features will be offset by life-cycle cost savings for heating, cooling, lighting, and ventilation.

Installation costs of the high-performance metal roofing, SIPS, fiber-reinforced siding materials, fly ash concrete, and recycled plastic lumber will be tabulated. A life-cycle cost analysis (LCCA) will be developed in accordance with the Corps of Engineers standard procedures. The analysis for each technology will be developed and compared with representative materials and components that would ordinarily be used in replacement or renovation. The key indicator of the project's economic feasibility will be how much the selected technologies contribute overall to the building's life-cycle performance.

The contractor's expenditures for the fly ash concrete foundation, SIPS panels, metal roofing, and siding are documented, as is their budget for the recycled plastic lumber structures. These cost figures will be compared with other standard materials that would be used in similar applications.

It is noted that the contractor's costs at this writing have been substantially higher than expected compared with commercial cost-estimating data and vendor information. Two examples are provided, each including material and installation but not including contractor overhead and profit:

- 10 in. SIPS, with 7/16 in. OSB faces and EPS cores:
 - R.S. Means Building Construction Cost Data — approximately \$8/sq ft
 - Actual contractor expenditure — approximately \$18/sq ft
- Zinc-aluminum alloy coated standing seam steel roofing (i.e. Galvalume), 24 ga.:
 - R.S. Means Building Construction Cost Data — approximately \$6/sq ft
 - Actual contractor expenditure — approximately \$18/sq ft

An independent cost analysis of the demonstrated systems is being conducted by a third party. Actual costs will be used in the project cost analysis. If the actual costs are verified to be unrealistically high, a reasonable cost figure will be identified for future reference as a more dependable benchmark for cost estimating.

4.1.2 Environmental costs

There are also environmental costs and savings that are not captured either as first costs or as part of a conventional LCCA methodology. Most environmental stressors associated with building materials occur during raw materials extraction, manufacturing, and transportation activities. Reusing lumber instead of landfilling it and manufacturing new lumber reduces the following environmental stressors as follows*:

Primary energy consumption:	78.3%
Solid waste:	99.9%
Air pollution index:	99.9%
Water pollution index:	98.6%
Water used:	100.0%
Weighted resource use:	97.3%

4.2 Projected return on investment

A formal return on investment study has not been performed at this writing. A contractor has been retained to perform the analysis when this project is complete, all initial costs are known, and life-cycle costs may be reliably projected.

* Napier, T.R., D.T. McKay, and N.D. Mowry. "A Life Cycle Perspective on Recycling Construction Materials" in *Construction Materials and Technologies*, Yoon-moon Chun, Peter Claisse, Tarun R. Naik, and Eshmaiel Ganjian, Eds. Presented at International Conference on Sustainable Construction Materials and Technologies, 11-13 June 2007, Coventry, UK. London: Taylor & Francis.

5 Conclusions and Recommendations

5.1 Conclusions

This demonstration has shown that corrosion-resistant materials may successfully be specified as part of a sustainability-driven building renovation project, and that the objectives of corrosion prevention and control are highly compatible with the goals of sustainable infrastructure. In particular, the CPC objectives of reducing maintenance requirements, extending facility service life, and reducing life-cycle costs directly complement core principles of infrastructure sustainability. The selected CPC technologies provide a high level of resistance to corrosive degradation caused by environmental exposure, which can extend the service life of existing structures by as much as 100 percent while eliminating the financial and environmental costs of demolishing such structures, preparing the site for new construction, and procuring a completely new facility.

At this writing, the successfully implemented technologies on this project are:

- sandwich-type structural insulated panels
- high performance standing seam metal roof
- fiber-reinforced polymer-cement siding
- fly ash content concrete foundations.

Recycled plastic lumber assemblies are expected to be installed during the summer 2008 timeframe, and will be documented with final project results in the final FAR-21 technical report.

Performance testing has not been executed at this writing owing in part to construction schedule delays. The performance characteristics of the selected technologies are well documented, however, both in published data and in unpublished data supplied to ERDC-CERL by the manufacturers. The primary characteristics of interest to the CPC Program are those indicating durability and resistance to corrosive degradation, including resistance to ingress of water, moisture, and humidity; and resistance to the effects of salt spray, chemical, and ultraviolet radiation exposure. Freeze-thaw cycling, airborne abrasives, and other environmental attacks are also areas of concern for future performance monitoring. The general perform-

ance data compiled by ERDC-CERL by the time of this writing suggest that the selected materials will provide an excellent level of performance in terms of corrosion prevention and control. Exposure racks will be built to monitor the performance of roofing and siding material samples. Accelerated weathering testing will also be conducted by ERDC-CERL and documented in the final technical report.

Some difficulties occurred with the construction contract and initial lapses in quality control, but those problems have been resolved and the final work is of the expected high quality. Diligent conformance to the manufacturers' installation instructions is being enforced where rework is necessary.

A formal economic analysis of the demonstrated technologies, including a return-on-investment calculation, will be included in the final technical report on this demonstration.

5.2 Recommendations

5.2.1 Applicability

All of the demonstrated technologies are applicable to renovation of WWII-era temporary wood buildings, and will contribute to extending their useful life. These technologies are expected to be equally applicable to the renovation of other building construction types and to new construction.

The SIPS panels are commonly applied to frame construction (either metal or wood) or used as vertical and horizontal load-bearing members. Current applications in the commercial market are largely residential and light commercial, and should be usable for any similar structural category on military installations.

The fiber-reinforced cement siding panels are also currently applied to frame construction, either wood or metal, in both renovation and new construction. The material also can be applied to masonry walls by using furring strips, but this application is not common at this time.

Fly ash concrete and standing-seam metal roofing are almost universally applicable. The metal roofing can be applied as an architectural roof (i.e., not load-bearing), similar to the E2C2 building, fastened to a substrate

supporting its entire surface. It also can be used as a structural element, spanning the secondary roof-framing members. Note that these two approaches differ significantly, and so the thickness of the roof panels and fastening details depend on the structure to which it is being attached.

Recycled plastic lumber components are widely applicable in any exterior application where conventional treated lumber is used and resistance to corrosive weathering effects is required. Because of its material properties, however, note that recycled plastic lumber is susceptible to creep. Therefore, plastic lumber components will either have to be larger than conventional lumber members in the direction of applied loads, or reinforced to resist creep, or used to span smaller dimensions.

5.2.2 Implementation

The demonstrated technologies can be implemented throughout DoD building programs using standard construction practices. An existing Unified Facilities Guide Specification (UFGS) is published for standing-seam metal roofing (UFGS 07 41 63, *Fabricated Roof Panel Assemblies*). The metal sheet material, zinc-aluminum galvanization (Galvalume), and PVDF coating are addressed in this specification, as are fasteners and other components of a standing-seam metal roof system.

Another existing guide specification, UFGS 03 30 00, *Cast-In place Concrete*, is published for concrete materials. This specification addresses the addition of fly ash to the concrete formulation, but does not require the addition of fly ash.

There is currently no UFGS for either SIPS or fiber-reinforced polymer cement siding. Development of a UFGS for each technology is recommended. The published performance data included in this report provide a basis for developing the specifications. In the interim, SIPS and fiber-reinforced polymer cement siding may be incorporated into design or retrofit projects. Specifications may be written on a job-by-job basis. Designers and specifiers are urged to obtain comprehensive data from potential suppliers, especially as related to load-carrying capabilities, attachment details, and resistance to both positive and negative pressure. Approval by the International Code Council, or one of the model building code organizations, through an ICC Legacy Report, or provision of an engineered alternative analyses, should be required in any project.

Appendix A: Project Management Plan for CPC Project FAR-21

RECLAMA

FAR 21: Sustainable Materials Replacement for Prevention of Corrosion (What specific materials and use – what products are new?)

General:

As stated in the Proposal, the goals for being sustainable are completely consistent with the goals of corrosion prevention and control. The overall plan for the proposed Project is to renovate an existing building using sustainable products and material systems in order to reduce:

- installation costs (first and lifecycle)
- operational costs (energy efficiencies and low maintenance requirements – more durable, reduced degradation)

as well as extend service life (again more durable, reduced degradation). Another objective for this “model” building is to obtain a high LEED (Leadership in Energy and Environmental Design, U.S. Green Building Council) rating consistent with Army goals for *Sustainability*.

What specific materials and use?:

- The wall structure will use structural insulated panels (such as, concrete-filled foam core, OSD and foam core, or foam and steel composites) incorporating high energy efficiencies with ease of construction (lower installation costs) and low lifecycle maintenance.
- Recycled plastic materials with a minimum 50-year life (low rate of degradation) will be used in the roofing system.
- The exterior cladding will be a reinforced polymer-cement laminate incorporating a moisture drainable system for reduced potential for material degradation from entrapped water in the wall cavity.
- “Green” concrete incorporating fly ash and recycled concrete aggregates will be used for the foundation, pavements, and walkways.
- Even the adhesives used in the construction will be engineered from bio-based components as environmentally friendly but highly durable materials.
- The finished building will be a showcase for a highly durable structure with low maintenance and operational costs.

What products are new?:

All of the products and systems described above are commercially available and mature enough for demonstration without undue risk. None of these product systems are in routine use on Army facilities and the proposed building renovation will be the first anywhere to utilize all of these products as a showcase “sustainable” building structure. While the use of recycled materials is mentioned as generic guidance (for example, the use of fly ash in concrete), none of the product systems above are specifically specified as sustainable under current DoD engineering databases. In addition, guidance is needed for the selection and use of these systems as a family of products in order to provide complete sustainable facilities (with a high LEED score). The products and systems to be utilized in this project would be directly applicable for use on facilities at all of the Services.

TRISERVICE PROGRAM

ARMY FACILITIES

CORROSION PREVENTION AND CONTROL PROJECT
PLAN

Sustainable Materials Replacement for Prevention of Cor-
rosion

at Fort Lewis (OMA)

02 June 2006

Submitted By:

Vincent Hock

U.S. Army Engineer Research & Development Center (ERDC)

Construction Engineering Research Laboratory (CERL)

Comm: 217-373-6753

Project Number – FAR21

1. STATEMENT OF NEED

PROBLEM STATEMENT: Billions of dollars are spent each year in the construction, operation, and maintenance of military facilities. Directives have come from the highest Command to make our military installations more “sustainable.” For example: Executive Order 13101 “Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition” and Engineering Technical Letter 1110-3-491 “Sustainable Design for Military Facilities.” Sustainable facilities can equate to reduced wastes (use of products with a recycled content), extended service life (more durable, **reduced degradation**), reduced operational cost savings (more efficient energy usage), reduced water usage (again a cost savings), reduced costs for initial installation, reduced lifecycle costs, and increased quality of life.

Of importance is that all of the above mentioned goals for sustainability are completely consistent with the goals of OSD’s Corrosion Prevention and Control Program.

Many sustainable products systems are now available that can be used in place of the more traditional material systems but which are more resistant to corrosion and materials degradation than the traditional materials. The non-use of these sustainable alternatives is typically due to the lack of awareness of their existence and the possible benefits. This project is needed to showcase and validate these benefits for a variety of sustainable, corrosion/**degradation**-resistant material products.

IMPACT STATEMENT: As long as there is a need for maintaining a military force, there will be a need for fixed facilities to train, house, and manage such a force. Facilities that require continued maintenance and repair or that require high energy to operate divert critical resources (time, people, and funds) that could otherwise be used to support the mission. The proposed corrosion resistant and sustainable materials systems will assure lower operating and maintenance costs for the life of the systems.

2. PROPOSED SOLUTION

TECHNICAL DESCRIPTION: A variety of new sustainable material systems have entered the market over the last decade. Such items include, but are not limited to, structural insulated panels wall systems, “green” concrete, insulating additives for paints, synthetic wood, recycled thermo-

plastic lumber, recycled carpets, bio-fiber reinforced composites, bio-based cements, and synthetic exterior wall claddings.

The overall plan for the proposed Project is to renovate an existing building using sustainable products and material systems in order to reduce:

- **installation costs (first and lifecycle)**
- **operational costs (energy efficiencies and low maintenance requirements – more durable, reduced degradation)**

as well as extend service life (again more durable, reduced degradation). Another objective for this “model” building is to obtain a high LEED (Leadership in Energy and Environmental Design, U.S. Green Building Council) rating consistent with Army goals for *Sustainability*.

As part of its mission, Fort Lewis maintains and operates several hundred buildings (does not include family housing). In this project, one of these building will undergo a complete renovation using a selection of sustainable material systems **as follows:**

- **The wall structure will use structural insulated panels (such as, concrete-filled foam core, OSD and foam core, or foam and steel composites) incorporating high energy efficiencies with ease of construction (lower installation costs) and low lifecycle maintenance.**
- **Recycled plastic materials with a minimum 50-year life (low rate of degradation) will be used in the roofing system.**
- **The exterior cladding will be a reinforced polymer-cement laminate incorporating a moisture drainable system for reduced potential for material degradation from entrapped water in the wall cavity.**
- **“Green” concrete incorporating fly ash and recycled concrete aggregates will be used for the foundation, pavements, and walkways.**
- **Even the adhesives used in the construction will be engineered from bio-based components as environmentally friendly but highly durable materials.**
- **The finished building will be a showcase for a highly durable structure with low maintenance and operational costs.**

Technology Maturity:

Sustainable material systems are commercially available from different manufacturers across the U.S. While the different systems are readily available, their existence and benefits are not well documented. A primary objective of the proposed project is to showcase the different sustainable products and to verify and document the corrosion resistance (durability and low maintenance requirements), economic (first and lifecycle costs) and the environmental (sustainable and “green”) benefits to the Army and the rest of DoD.

All of the products and systems described above are commercially available and mature enough for demonstration without undue risk. None of these product systems are in routine use on Army facilities and the proposed building renovation will be the first anywhere to utilize all of these products as a showcase “sustainable” building structure. While the use of recycled materials is mentioned as generic guidance (for example, the use of fly ash in concrete), none of the product systems above are specifically specified as sustainable under current DoD engineering databases. In addition, guidance is needed for the selection and use of these systems as a family of products in order to provide complete sustainable facilities (with a high LEED score).

Implementation of the sustainable material systems at Fort Lewis is projected to have an ROI of 14.92, and a total savings of \$16,297,933.

RISK ANALYSIS: This is a **low-risk** project as all of the sustainable products being considered are commercially available and have been successfully used in similar applications. The site for implementation of this project at Fort Lewis and plans for implementation of this project have been coordinated with the DPW Office. The project will not be parsed into phases.

EXPECTED DELIVERABLES AND RESULTS/OUTCOMES: Sustainable products are commercially available and will be used to renovate a selected building at Fort Lewis. After surveying the candidate building and coordinating with the DPW on functional requirements, a design will be completed for the renovation that will utilize a selected variety of sus-

tainable products. After Installation approvals, the existing building will be gutted and the new sustainable product systems installed.

The economics and performance benefits of the sustainable systems will be analyzed and documented. The project design and benefits analyses will be used to develop new or modify existing engineering guidance (e.g., Unified Facilities Guide Specifications – UFGS and Unified Facilities Criteria – UFC) for the demonstrated sustainable products. A final report describing the details of the project will be developed and placed on the OSD Corrosion Exchange website under “Specs & Standards” and “Facilities SIG.” In addition, the draft documents will be posted on the ERDC-CERL Corrosion Control Technology Program (CCTP) website.

PROGRAM MANAGEMENT: The Project Manager will be: Mr. Vincent Hock (ERDC-CERL Senior Researcher and Materials Engineer). The Associate Project Manager will be: Mr. Richard Lampo. Mr. Martin Savoie is the ERDC-CERL Branch Chief. The stakeholders will be: the Fort Lewis DPW, Mr. Steve Glover and Mr. Ken Smith (Fort Lewis DPW), Mr. Tom Shields (IMA-NWRO), Paul Volkman (HQ-IMA), David Purcell (HQ-ACSIM), as well as Tri-services WIPT representatives, Mr. Tom Tehada (NFESC), and Ms. Nancy Coleal (AFCEA/CESM). The initial customer is the Directorate of Public Works, Fort Lewis, WA. The technology has been requested by Fort Lewis to help reduce their renovation and operational maintenance and repair costs of their many buildings.

Fort Lewis has provided matching funds of \$650K – \$500K through HQ-IMA (See Memorandum from ACSIM Director for Facilities and Housing in Appendix 2) plus \$150K Installation OMA. Coordination with the Army Corrosion Program Office will be through Mr. Hilton Mills (HQ-AMC).

This is a Tri-service Project. Funds have been requested for travel of Air Force and Navy representatives to participate in the evaluation of technology implementation.

3. COST/BENEFITS ANALYSIS

a. **Funding (\$K):**

	Fort Lewis Matching		
Funding Source	OSD	IMA	OMA
Labor	127	140	39
Contracts	100	152	50
Materials	110	200	61
Travel	21	8	--
Report	50	--	--
Air Force/Navy Participation	23	--	--
TOTAL (\$K)	431	500	150

Development Project Budget

The \$1.09M budget is realistic and adequate for the scope of the project. This budget has been based on a needs assessment of the candidate facilities at Fort Lewis. ERDC-CERL has extensive previous experience with the different sustainable systems to be used in this demonstration.

b. **Return-On-Investment Computation:**

Using the required OMB spreadsheet, and in accordance with OMB Circular A-94, a **return-on-investment (ROI) of 14.92** was calculated (see Appendix 1 below for assumptions made in this calculation). The **associated savings were \$16,298M**. This ROI value is based on current best practices, as well as projected maintenance and rehabilitation practices and costs.

c. **Mission Criticality:**

A military installation can not operate without buildings but buildings demand high costs for their operation and maintenance-and-repair. Buildings house not only people but critical equipment and mission command staff. Buildings that require high maintenance drain the installation of dollars to support the mission. Failed buildings or building components can mean loss of that function or operation within that building. Failed buildings can also jeopardize

the safety and security of not only those who normally use or occupy the structure but everyone on the installation.

SCHEDULE

MILESTONE CHART

EVENT	TIME (months after receipt of funds)
Site Visit to Survey Candidate Building	2
Award Contract for Design Work	3
Detail Needed Systems to Demonstrate	4
Award Contract and Initiate Renovations	7
Complete Renovations of Building	10
Perform Follow Up Assessment	14
Complete Documentation (includes Final Report, Procurement Specification, Ad Fliers)	16
Complete ROI Validation	16

a. Note: If project is approved, ***bi-monthly status reports will be submitted*** (i.e. starting the first week of the second month after contract award and every two months thereafter until final report is completed). This report will be submitted to the DoD CPC Policy & Oversight office. Report will include project number, progress summary (and/or any issues), performance goals and metrics and upcoming events.

- b. Examples of performance goals and metrics: include achieving specific milestones, showing positive trend toward achieving the forecasted ROI, reaching specific performance quality levels, meeting test and evaluation parameters, and/or successfully demonstrating the new systems.

Development Project Schedule

This project to renovate an existing building with sustainable material systems will be completed, including the final report, within 16 months. Performance, economic, and environmental benefits will be documented. Engineering guidance documents will be developed to enable others to design and use the innovative material systems. Design and construction using the sustainable material systems will be done by contractors. ERDC-CERL will provide overall management, technical guidance, contract monitoring, and provide bi-monthly progress reports. The schedule has been coordinated with Fort Lewis DPW. Project milestones are shown in the Table above.

5. IMPLEMENTATION

a. Transition approach: The project design and benefits analyses will be used to develop new or modify existing engineering guidance (e.g., Unified Facilities Guide Specifications – UFGS and Unified Facilities Criteria – UFC) for the demonstrated sustainable products. A final report describing the details of the project will be developed and placed on the OSD Corrosion Exchange website under “Specs & Standards” and “Facilities SIG.” In addition, the draft documents will be posted on the ERDC-CERL Corrosion Control Technology Program (CCTP) website. Coordination with potential users will be an essential part of the transition of the technology. **The products and systems to be demonstrated in this project would be directly applicable for use on facilities at all of the Services.**

b. ROI validation: Potential ROI will be validated by comparison of replacement of conventional wood timber bridge design at the site location. The calculated ROI for this project, which is based on current best practices, projected maintenance and rehabilitation cost, has the potential to increase over the multiple year implementation due to the reduction in down time, which will result in increased indirect savings.

Third party validation will be used to document the ROI savings performance of this project. This validation work will be performed by an impartial and technically qualified individual.

c. Final Report: A final report will be written 60 days after the project is completed. The report will reflect the project plan format as implemented and will include lessons learned.

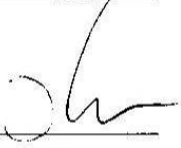

Projected Benefits

The sustainable material systems being demonstrated in this project will provide reduced maintenance facilities of normal service life. In addition, the renovated building will offer a greater quality of life than with the systems being replaced.

Management Support

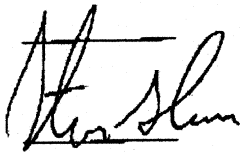
This project is supported by the Fort Lewis DPW Office as well as the IMA-NERO Region (see coordination sheet signatures). In addition, the Army (HQ-IMA and HQ-ACSIM) have reviewed this project and provided matching funds for FY06. See associated Memorandum from ACSIM Director for Facilities and Housing in Appendix 2.

6. COORDINATION SHEET

<u>ORGANIZATION</u>	<u>SIGNATURE</u>	<u>DATE</u>
Associate Project Manager		6/14/05
Project Manager	Vincent F. Ford	6/14/05
ERDC-CERL Brach Chief, CF-M		6/14/05
Fort Lewis DPW	_____	_____
IMA Northwest Region	_____	_____
HQ IMA	_____	_____
HQ ACSIM	_____	_____
HQ AMC	_____	_____
Tri-Service Facilities WIPT Chair	_____	_____


This is a Tri-Service Project. Funds have been requested for Air Force and Navy representatives to participate in the evaluation of technology implementation.

6. COORDINATION SHEET

<u>ORGANIZATION</u>	<u>SIGNATURE</u>	<u>DATE</u>
CERL Project Manager	_____	_____
CERL Associate Project Manager	_____	_____
Fort Lewis DPW		<u>13 Jun 05</u>
IMA Northwest Region	_____	_____
HQ IMA	_____	_____
HQ ACSIM	_____	_____
HQ AMC	_____	_____
Tri-Service Facilities WIPT Chair	_____	_____


This is a Tri-Service Project. Funds have been requested for Air Force and Navy representatives to participate in the evaluation of technology implementation.

6. COORDINATION SHEET

<u>ORGANIZATION</u>	<u>SIGNATURE</u>	<u>DATE</u>
Associate Project Manager	_____	_____
Project Manager	_____	_____
ERDC-CERL Brach Chief, CF-M	_____	_____
Fort Lewis DPW	_____	_____
IMA Northwest Region		9/22/05
HQ IMA	_____	_____
HQ ACSIM	_____	_____
HQ AMC	_____	_____
Tri-Service Facilities WIPT Chair	_____	_____

This is a Tri-Service Project. Funds have been requested for Air Force and Navy representatives to participate in the evaluation of technology implementation.

6. COORDINATION SHEET

<u>ORGANIZATION</u>	<u>SIGNATURE</u>	<u>DATE</u>
CERL Project Manager	_____	_____
CERL Associate Project Manager	_____	_____
CERL Brach Chief, CF-M	_____	_____
Fort Lewis DPW	_____	_____
IMA Northeast Region	_____	_____
HQ IMA		6/15/05
HQ ACSIM	_____	_____
HQ AMC	_____	_____
TriService Facilities WIPT Chair	_____	_____

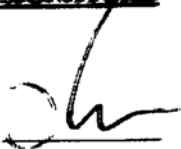
This is a TriService Project. Funds have been requested for Air Force and Navy representatives to participate in the evaluation of technology implementation.

6. COORDINATION SHEET

<u>ORGANIZATION</u>	<u>SIGNATURE</u>	<u>DATE</u>
CERL Project Manager	_____	_____
CERL Associate Project Manager	_____	_____
CERL Branch Chief, CF-M	_____	_____
Fort Lewis DPW	_____	_____
IMA Northwest Region	_____	_____
HQ IMA	_____	_____
HQ ACSIM	<i>A. Russell</i>	<i>15 June 05</i>
HQ AMC	_____	_____
Tri-Service Facilities WIPT Chair	_____	_____

This is a Tri-Service Project. Funds have been requested for Air Force and Navy representatives to participate in the evaluation of technology implementation.

6. COORDINATION SHEET

<u>ORGANIZATION</u>	<u>SIGNATURE</u>	<u>DATE</u>
Associate Project Manager		6/14/05
Project Manager	Vincent R. Bell	6/14/05
ERDC-CERL Beach Chief, CF-M	Matthew	6/14/05
Fort Lewis DPW	_____	_____
IMA Northwest Region	_____	_____
HQ IMA	_____	_____
HQ ACSIM	_____	_____
HQ AMC	_____	_____
Tri-Service Facilities WIPT Chair	Thomas Schade	6/15/05

This is a Tri-Service Project. Funds have been requested for Air Force and Navy representatives to participate in the evaluation of technology implementation.

7. APPENDICES

APPENDIX 1: Return on Investment (ROI) Calculations based on OMB Circular A-94

Assumptions:

- a. Assume implementation of this technology on twenty five (25) buildings at Fort Lewis at \$500K each for conventional technologies. Replacement is needed immediately which calculates as \$12.5M. Assume major renovation after ten (10) years at \$1.875M (\$75K per building) and complete replacement at twenty years for the conventional material systems (\$12.5M). Assume minor upgrades (\$150,000 total) to the sustainable systems after ten (10) and twenty (20) years.
- b. Assume annual maintenance and operational energy costs per building for both the conventional and the sustainable systems with the sustainable costs at one-third the cost of the conventional systems (that is, \$75,000 versus \$25,000).
- c. Even with routine maintenance, failures of the conventional material systems will still occur due to materials degradation with a direct (e.g., higher energy costs, rental facilities, etc.) and indirect cost (loss of mission use) impact of \$50,000 figured on a periodic basis of every three years.

Attachment 1 – ROI Computation

Return on Investment Calculation

Investment Required			1,092,000
Return on Investment Ratio	14.92	Percent	1492%
Net Present Value of Costs and Benefits/Savings	417,708	16,715,700	16,297,993

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	12,575,000		25,000		23,365	11,752,595	11,729,230
2	75,000		25,000		21,835	65,505	43,670
3	75,000		25,000	50,000	20,408	102,038	81,630
4	75,000		25,000		19,073	57,218	38,145
5	75,000		25,000		17,825	53,475	35,650
6	75,000		25,000	50,000	16,658	83,288	66,630
7	75,000		25,000		15,568	46,703	31,135
8	75,000		25,000		14,550	43,650	29,100
9	75,000		25,000	50,000	13,598	67,988	54,390
10	75,000		25,000		12,708	38,123	25,415
11	1,950,000		175,000		83,143	926,445	843,303
12	75,000		25,000	50,000	11,100	55,500	44,400
13	75,000		25,000		10,375	31,125	20,750
14	75,000		25,000		9,695	29,085	19,390
15	75,000		25,000	50,000	9,060	45,300	36,240
16	75,000		25,000		8,468	25,403	16,935
17	75,000		25,000		7,915	23,745	15,830
18	75,000		25,000	50,000	7,398	36,988	29,590
19	75,000		25,000		6,913	20,738	13,825
20	75,000		25,000		6,460	19,380	12,920
21	12,575,000		175,000	50,000	42,263	3,048,938	3,006,675
22	75,000		25,000		5,643	16,928	11,285
23	75,000		25,000		5,273	15,818	10,545
24	75,000		25,000	50,000	4,928	24,638	19,710
25	75,000		25,000		4,605	13,815	9,210
26	75,000		25,000		4,305	12,915	8,610
27	75,000		25,000	50,000	4,023	20,113	16,090
28	75,000		25,000		3,760	11,280	7,520
29	75,000		25,000		3,515	10,545	7,030
30	75,000		25,000	50,000	3,285	16,425	13,140

APPENDIX 2. IMA Matching Funds Letter:



DEPARTMENT OF THE ARMY
ASSISTANT CHIEF OF STAFF FOR INSTALLATION MANAGEMENT
600 ARMY PENTAGON
WASHINGTON DC 20310-0600

25 MAR 2005

DAIM-FD

S: 15 Oct 2005

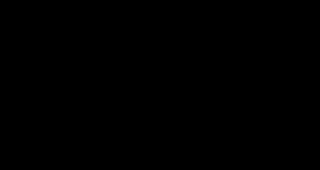
MEMORANDUM FOR DIRECTOR, INSTALLATION MANAGEMENT AGENCY, 2511
JEFFERSON DAVIS HIGHWAY, ARLINGTON VA 22202-3926

SUBJECT: FY 06 Army Corrosion Control Program

1. OSD has tentatively allocated a total of \$15.0M in FY 06 matching funds for implementation of corrosion prevention and control projects for equipment and facilities. The enclosed list of Army projects, totaling \$13.3M, will be presented for approval to OSD in April 05.
2. The Army programming target is not less than \$10.0M of facility related projects in an effort to obtain a minimum of \$5.0M of the OSD matching funds. To participate in OSD's funding augmentation, HQIMA will reserve \$5.0M in FY06 OMA funds, to be released to ERDC-CERL upon confirmation by this office that OSD matching funds are available. Further instructions on the actual distribution of funds will follow at that time.
3. POC for this action is Mr. David N. Purcell, or (703) 601-0371, David.Purcell@hqda.army.mil.
4. Quality Facilities for Quality Soldiers!

FOR THE ASSISTANT CHIEF OF STAFF FOR INSTALLATION MANAGEMENT:

Encl
as


MARK A. LORING
Colonel, GS
Director, Facilities and Housing

CF:
DACSIM

Appendix B: Contractor Planning and Safety Documents

FORT LEWIS ENVIRONMENTAL EDUCATION & CONFERENCE
CENTER (E2C2)- SEQUALITCHEW ECO- PARK
Fort Lewis, Washington

SAFETY MANAGEMENT PLAN

Contract No. DACW67-03-D-1003
Task Order 0008

Prepared for
US Army Corps of Engineers, Seattle District



US Army Corps
of Engineers ®

December 5, 2006

CONTRACTOR: MCS Environmental, Inc.
CONTRACT NUMBER: DACW67-03-D-1003
TO 0008

TRANSMITTAL NUMBER: Appendix-1

ITEM NUMBER: 3

SPECIFICATION SECTION: Appendix

PARAGRAPH NUMBER: c

____ **APPROVED AS SUBMITTED**

____ **APPROVED WITH CORRECTIONS
AS NOTED**

SIGNATURE: 

TITLE: Project Manager

DATE: December 5, 2006

MCS Environmental, Inc.
Environmental Logic

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Fort Lewis Environmental Education & Conference Center (E2C2)
Sequalitchew Eco Park
Fort Lewis, Washington

ENVIRONMENTAL PROTECTION PLAN

Contract No. DACW67-03-D-1003
Task Order 0008

Prepared for
US Army Corps of Engineers, Seattle District



US Army Corps
of Engineers ®

December 12, 2006

CONTRACTOR: MCS Environmental, Inc.
CONTRACT NUMBER: DACW67-03-D-1003
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ITEM NUMBER: 4
SPECIFICATION SECTION: Appendix
PARAGRAPH NUMBER: e
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☐ **APPROVED WITH CORRECTIONS**
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SIGNATURE: 
TITLE: Project Manager
DATE: December 12, 2006

 Environmental, Inc.
Environmental Logic

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FORT LEWIS ENVIRONMENTAL EDUCATION & CONFERENCE
CENTER (E2C2)- SEQUALITCHEW ECO- PARK
Fort Lewis, Washington

CONTRACTOR QUALITY CONTROL PLAN

Contract No. DACW67-03-D-1003
Task Order 0008

Prepared for
US Army Corps of Engineers, Seattle District



US Army Corps
of Engineers ®

December 5, 2006

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14. ABSTRACT This report documents a building reclamation project at Fort Lewis, WA, in which significant portions of the work were completed using market-available sustainable replacement materials. The replacement materials were selected on the basis of their being more resistant to corrosion and materials degradation processes than conventional construction materials, and also because they also are expected to provide long-term benefits to the U.S. Army in terms of operation and maintenance cost reductions. The demonstration was applied to the reclamation and renovation of a World War II-era temporary wood frame chapel building, which was otherwise slated for demolition and off post landfill disposal. The structure was moved intact from its original site to the Sequelitchew EcoPark at Fort Lewis, to be renovated and reused as the installation's new Environmental Education and Conference Center (E2C2). This report describes project objectives, materials selection, and renovation activities to date. Existing performance data was compiled and reviewed, and selected physical testing will be conducted once all installation activities are complete. A return-on-investment analysis will be performed to verify the life-cycle cost benefits projected for the project in terms of operations and maintenance cost benefits, including the control and prevention of corrosion and building materials degradation.					
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